Chapter 12
Crystal Plasticity Based Modelling of Deformation Textures

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Abstract. Focus is on the multi-level character of existing or currently developed models for polycrystal deformation. A short overview is presented of two-level models ranging from the full-constraints Taylor model to the crystal-plasticity finite element models, including the description of a few recent and efficient models (GIA and ALAMEL). Validation efforts based on experimental cold rolling textures obtained for an aluminium and a steel alloys are discussed.

12.1 Introduction

Crystallographic textures are responsible for anisotropy of the mechanical behaviour of the material. This includes the strength of the metal which varies with the direction in which it is measured; the $r$-value (ratio between plastic strain to thickness plastic strain in a tensile test), which also varies with the test direction; other measures of formability, such as the limiting drawing ratio in a cup test and the earing behaviour. During the forming of a car body sheet, thickness distribution and failure will also be influenced by the texture; so finite element (FE) simulations of such processes should take texture-induced anisotropy into account. In principle they should also take the evolution of the texture during the forming operation into account, because the mechanical anisotropy also changes when the texture changes. Since the latter (effect of texture on yield stress etc.) is a quantitative effect, it is clear that any model used by the FE code to simulate the evolution of the texture must also be quantitatively correct. This implies that validations –
i.e. comparison of predicted deformation textures with measured ones – must be done in a quantitative way. In the present paper, these comparisons will be based on ODFs using the Bunge [1] convention. Validations were done for one aluminium alloys (AA1200) and for IF steel. These are single-phase materials.

The texture of metal sheets which have been hot rolled has been measured using X-ray diffraction. The sheets have then been cold rolled (various thickness reductions). The texture has been measured again after the last cold rolling pass (prior to annealing), and in some cases also after some intermediate rolling passes. The ODF (Bunge [1]) has been calculated for all these textures. The ODFs of transfer slab textures have been transformed into sets of discrete orientations and then used as starting textures of the simulations of the rolling textures. Various methods have been used for these simulations, ranging from the full-constraints Taylor method (FC Taylor) to the crystal plasticity finite element method (CPFEM). Some of these methods focus on the interaction between neighbouring grains, and these methods were found to give the best results.

### 12.2 Crystal Plasticity Based Models

#### 12.2.1 General

It is assumed that plastic deformation is achieved by means of crystallographic slip on \{111\}<110> slip systems (fcc metals) or on \{110\}<111> combined with \{112\}<111> slip systems (bcc metals, such as low carbon steel). So in fcc metals, there are 12 slip systems which can (but do not need) be simultaneously active. In bcc metals, there are 24 of them (at least as assumed in the present paper). In principle all models to be discussed take the generalised Schmid law for the plastic deformation of crystals into account. This law states that a slip system is active when the resolved shear stress reaches a critical level, the “critical resolved shear stress” \( \tau_c \). The resolved shear stress is the “effect” of the applied stress on a particular slip system. Some models that will be discussed use the visco-plastic approximation of the generalised Schmid law. In most models, the same value is

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*Fig. 12.1* Shape of a stack of two grains after plane strain (as approximation for the deformation in the mid-plane of a rolling process), according to several statistical models. (a) Taylor full constraints model. (b) LAMEL model. (c) Pancake Relaxed Constraints model.